ANNUAL SUMMARY REPORT

01/01/2017 – 31/12/2017

INDEX

1 DESCRIPTION OF THE COGENERATION PLANT

The cogeneration plant of the company [redacted] consists of a combined cycle made up of two 4,845 kWe natural gas reciprocating engines and a 269 kWe steam turbine.

The exhaust gases from the reciprocating engines are directed to a mixed recovery steam generator (MRS) to produce saturated steam at 9.5 bar(g). Most of the steam generated is used to meet the thermal demands of the production process, and the remainder is fed into the condensing steam turbine to generate electricity.

When the steam generated on the recuperator side of the combination boiler is not sufficient to meet the demand of the production process, steam is generated in the boiler using the natural gas burner.

The steam intended for the process and degasser passes through a regulating valve, resulting in a pressure of 7 bar(a).

An auxiliary boiler is available to generate steam at 7 bar(a), fueled by natural gas, but it is not currently in use.

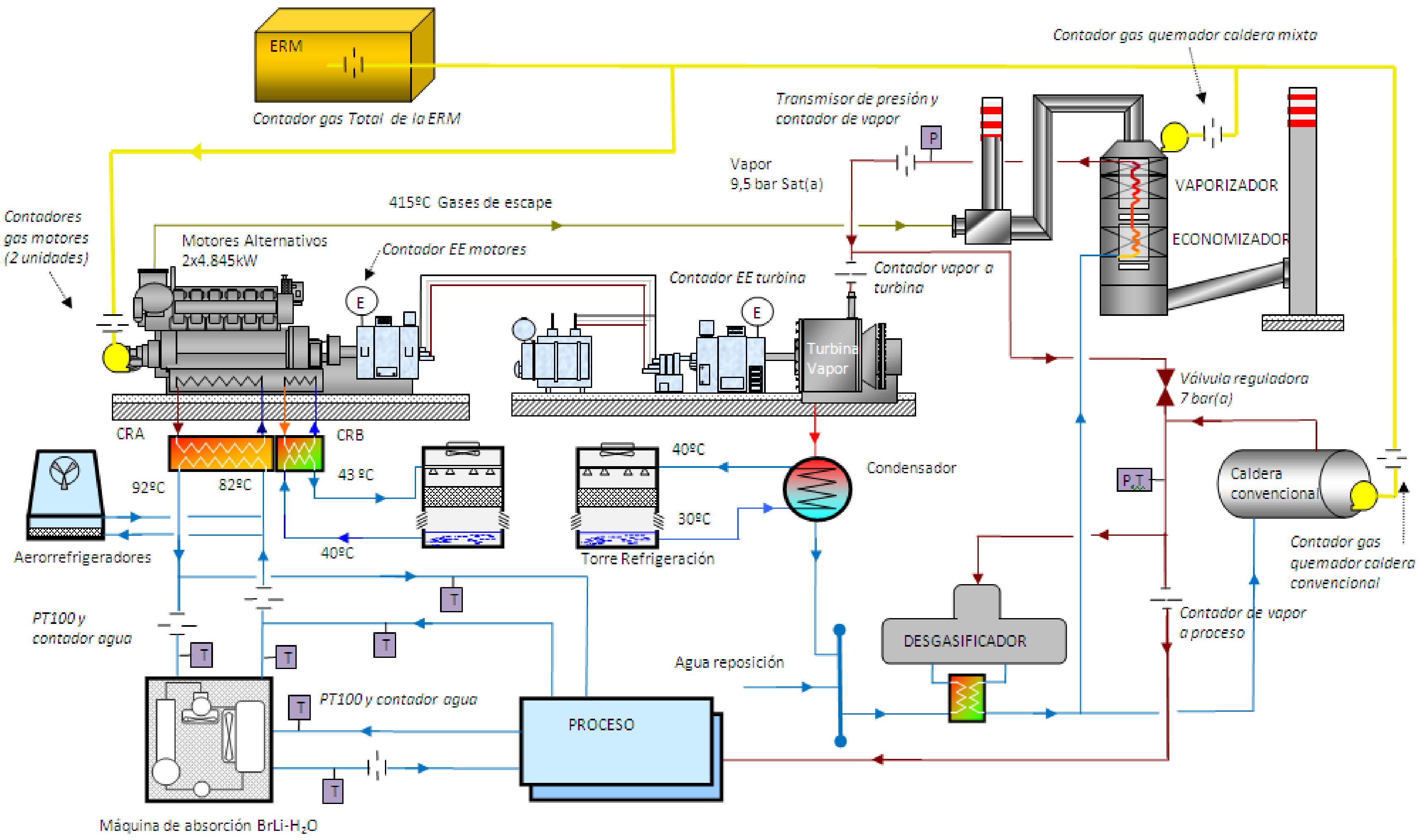
The thermal energy from the high-temperature cooling circuit of the engines (CRA) is used to cover the thermal demand for hot water in the factory and in the absorption machine generator.

The cold water generated in the absorption machine is used in the production process.

There is no thermal recovery of the energy contained in the low-temperature cooling circuits of the engines (CRB), which is dissipated by means of a cooling tower.

There is a single gas line that supplies all equipment (engines, mixed recovery boiler and auxiliary boiler).

Due to technical problems, the steam turbine has been shut down all year.


ERM
Contador gas Total de la ERM
Contador gas quemador caldera mixta
Transmisor de presión y contador de vapor
P
Vapor
9,5 bar Sat(a)
VAPORIZADOR
ECONOMIZADOR
415ºC Gases de escape
Contadores gas motores (2 unidades)
Motores Alternativos 2x4.845kW
Contador EE motores
E
Contador EE turbina
Contador vapor a turbina
Turbina Vapor
Válvula reguladora 7 bar(a)
CRA
CRB
92ºC
82ºC
43 ºC
40ºC
40ºC
30ºC
Condensador
Aerorrefrigeradores
Torre Refrigeración
P.T.
Caldera convencional
Contador gas quemador caldera convencional
T
PT100 y contador agua
Agua reposición
DESGASIFICADOR
Contador de vapor a proceso
PT100 y contador agua
PROCESO
Máquina de absorción BrLi-H₂O

The main equipment of the installation are:

1.1 ENGINES

2 ROLLS-ROYCE brand reciprocating engines, model BV12G at 750 rpm, whose technical characteristics are as follows:

- Electrical power (cos φ = 1): 4,845 kWe
- Natural gas consumption 10,161 kW
- Nominal electrical efficiency: 47.7%

1.2 COMBINATION STEAM BOILER

- Type: Fire-tube
- Fluid: Vapor
- Pressure: 9.5 bar(a)
- Steam production on the recovery side: 6,500 kg/h
- Steam production at the burner: 6,000 kg/h

1.3 CONDENSING STEAM TURBINE

- Vapor pressure: 9 bar(a)
- Steam temperature: 175ºC (sat.)
- Steam flow rate: 3,700 kg/h
- Exhaust backpressure: 0.14 bar(a)
- Electrical power: 269kW

Condenser (vacuum pressure 0.14 bar)

Envelope side

- Fluid:	water vapor
- Flow rate:	3,700kg/h
- Vacuum pressure:	0.14 bar (a)

Tube side

- Fluid:	Tower water
- Inlet temperature:	30ºC
- Outlet temperature:	40ºC
- Power dissipated:	2.460kW

1.4 Absorption Machine

- Cooling capacity:	1,200kW
- COP:	0.62
- Energy source:	hot water
- Absorbent:	Li Br
- Coolant:	water

Evaporator

- Fluid: water
- Inlet temperature: 12ºC
- Outlet temperature: 6ºC
- Flow rate: 172 m3/h

Absorber/Condenser

- Fluid: Tower water
- Water inlet temperature: 30ºC
- Water outlet temperature: 33.78ºC
- Water flow rate: 719m ^{3} /h

Generator

- Fluid: Hot water
- Water inlet temperature: 95ºC
- Water outlet temperature: 82ºC
- Water flow rate: 128m ^{3} /h

Cooling tower

- Power: 3,160kW
- Outlet temperature: 30ºC
- Inlet temperature: 33.78ºC

2 METHOD FOR CALCULATING THE REE

Current legislation requires that, in order for a cogeneration installation with alternative natural gas engines to qualify for the special regime for the production of electricity, and benefit from the rights inherent to such condition, it must obtain an "Equivalent Electrical Efficiency" equal to or greater than **55%** .

The Equivalent Electrical Performance (REE) as it appears in Annex I of Royal Decree 661/2007 is as follows:

$$REE = \frac{E_e}{Q - \frac{H}{Ref\ H}}$$

where,

E_e = Electrical energy generated, in thermal units. It will be equal to the electrical energy generated by the two motors plus that generated by the turbine.

Q = Thermal consumption of the cogeneration plant, measured by the lower heating value of the fuel. This would be the total annual consumption of the two engines.

H = Useful energy sent to the process, from the cogeneration plant.

Ref. H = Reference value for separate heat production, which appears in Annex II of Commission Delegated Regulation (EU) 2015/2402 of 12 October 2015 (for CERM, the corresponding value for hot water is 90%, and for steam without condensate return is 90%).

2.1 ENERGY SENT TO THE PROCESS (H_{CHP})

The useful energy sent to the process by the cogeneration plant, in this case, is subdivided into three:

$$H_{CHP} = H1 + H2 + H3$$

H1 = Energy Recovered by Steam at Factory

The steam meter is located in the process duct, measuring the steam flow generated in the mixed recovery steam generator (MRSG). The cogeneration heat is the amount measured by the meter minus the gas consumption of the MRSG burner multiplied by the reference thermal efficiency: $H_{CHP} = H – F_{noCHP} \cdot Ref\ H$

There is no return of process condensates, so the water supplied to cogeneration (m_A) is considered to be equal to the flow rate of steam delivered to the process (m_V).

According to the IDAE Technical Guide for Measuring Useful Heat, installations prior to RD 661/2007 can measure the heat recovered from steam according to the following expression [equation 7 of the Guide], only for the purpose of verifying the REE and in no case to charge the efficiency supplement:

$$H = m_V \cdot (h_{VAPOR} – h_{FEEDING\ WATER})$$

Where:

- $m_V = m^3$/h of steam sent to factory
- h vapor = Enthalpy of steam delivered to process
- h water input = Enthalpy of water in liquid state at 15º C and atmospheric pressure

The following data is collected from the steam meters:

month	Steam Generated [t/mes]	Steam turbine [t/mes]	Process steam [t/mes]	H steam to process [kWh/month]
Jan-17	1,873	0.00	1,795	1,348,867
Feb-17	1,666	0.00	1,598	1,202,418
Mar-17	1,689	0.00	1,615	1,214,162
Apr-17	2,560	0.00	2.461	1,845,002
May 17	2,447	0.00	2,356	1,771,882
June 17	2,578	0.00	2,487	1,870,573
Jul-17	2,941	0.00	2,834	2,132,172
Aug-17	1,688	0.00	1,599	1,201,974
Sep-17	2,046	0.00	1953	1,469,055
Oct-17	1,723	0.00	1,640	1,233,834
Nov-17	2,975	0.00	2,870	2,158,821
Dec-17	2,886	0.00	2,779	2,089,496
TOTAL	**27.072**	0.00	**25,987**	**19,538,256**

The heat of cogeneration (H_{CHP}) is calculated from the expression

$H_{CHP} = H - F_{noCHP} \cdot Ref\ H$

Being,

Ref. H: Reference value for efficiency for separate steam production, which in the case of CERM is 90%:

$F_{no\ CHP}$: Natural gas consumed in the mixed recovery boiler burner, measured from the gas meter of said burner.

month	*Boiler Burner Rec. [Nm ³ /month]*	*PCI [kWh/Nm ³]*	*F no CHP [kWhPCI/month]*
Jan-17	498	10,646	5,300
Feb-17	568	10,539	5,982
Mar-17	4.242	10,540	44,713
Apr-17	2,448	10,505	25,713
May 17	291	10,570	3,080
June 17	163	10,572	1,729
Jul-17	5	10,574	48
Aug-17	172	10,448	1,800
Sep-17	0	10,393	0
Oct-17	142	10,388	1.471
Nov-17	28	10,486	294
Dec-17	406	10,497	4.267
TOTAL	**8,963**	**10,513**	**94.397**

$H_{CHP} = H - F_{noCHP} \cdot Ref\ H = 19{,}538{,}256 - 0.90 \cdot 94{,}397 = 19{,}453{,}299$ kWh/year

Therefore,

H1 = 19,453,299 kWh/year

H2 = Energy Recovered by Hot Water for Factory

Part of the energy from the high-temperature cooling circuit of the engines is used to heat water in the fiber manufacturing process, via a heat exchanger. According to the guide [equation 5], the calculation of the recovered heat is:

$$H2 = m \cdot Ce \cdot (T_1 - T_2)$$

- m = Hot water flow sent to process
- Ce = Specific heat of water [1 kcal/kgºC]
- T_1 = Temperature at process inlet
- T_2 = Process return temperature

The following are the monthly data from the meters (heat integrator):

month	*H2 [kWh/month]*
Jan-17	758,395
Feb-17	389,427
Mar-17	702,850
Apr-17	785,659
May 17	429,929
June 17	405,852
Jul-17	478,056
Aug-17	586,698
Sep-17	352,824
Oct-17	301.473
Nov-17	712,418
Dec-17	818,492
TOTAL	**6,722,073**

Therefore,

H2 = 6,722,073 kWh/year

H3 = Energy Recovered in **the Absorption Machine**

The heat used for generating cold at a temperature level above 0º C by means of an absorption machine corresponds to the final cooling demand.

However, cogeneration plants prior to RD 661/2007 may consider the heat supplied to the absorption machine, only for the purpose of verifying the minimum REE required (and never for obtaining the efficiency supplement).

The calculation of the heat recovered in the case of liquid water is performed according to the following expression [equation 5 of the Guide]:

$$H3 = m \cdot Ce \cdot (T_1 - T_2)$$

- m = Hot water flow rate
- Ce = Specific heat of water [1 kcal/kgºC]
- T_1 = Temperature at process inlet
- T_2 = Process return temperature

An energy integrator is available to measure the cooling supplied to the process as well as the heat from the CRA supplied to the absorption chiller. The data recorded during 2016 are as follows:

month	*Heat absorption machine [kWh/month]*
Jan-17	307,214
Feb-17	497,901
Mar-17	469,910
Apr-17	660.708
May 17	758,766
June 17	678.236
Jul-17	815,767
Aug-17	817,466
Sep-17	735,377
Oct-17	821,530
Nov-17	583,940
Dec-17	586,676
TOTAL	**7,733,491**

H3 (heat supplied to absorption machine) = 7,733,491 kWh/year

Therefore,

H1 = 19,453,299 kWh/year

H2 = 6,722,073 kWh/year

H3 = 7,733,491 kWh/year

H_{CHP} = H1 + H2 +H3 = 33,908,863 kWh/year

2.2 ELECTRICITY PRODUCTION

The electrical energy generated during the period studied was:

- Engine 1: 34,791,200 kWh
- Engine 2: 27,032,400 kWh
- Steam turbine: 0 kWh

- **TOTAL: 61,823,600 kWh**

month	*Engine No. 1 [kWh/month]*	*Engine No. 2 [kWh/month]*	*Steam turbine [kWh/month]*	*TOTAL [kWh/month]*
Jan-17	3,516,510	1,272,410	0	4,788,920
Feb-17	3,129,290	954.070	0	4,083,360
Mar-17	3,253,240	932.520	0	4,185,760
Apr-17	2,965,250	2,604,960	0	5,570,210
May 17	2,754,040	2,486,820	0	5,240,860
June 17	2,038,600	3,275,610	0	5,314,210
Jul-17	2,748,500	3,141,000	0	5,889,500
Aug-17	2,272,120	2,530,120	0	4,802,240
Sep-17	2,978,010	2,190,100	0	5,168,110
Oct-17	3,047,600	1,413,180	0	4,460,780
Nov-17	2,963,410	3,044,010	0	6,007,420
Dec-17	3,124,630	3,187,600	0	6,312,230
TOTAL	**34,791,200**	**27,032,400**	**0**	**61,823,600**

2.3 CONSUMPTION IN THE FACILITY

The natural gas consumption in the cogeneration plant has been:

- Natural Gas Consumption in Engine 1: 7,770,249 Nm^3
- Natural Gas Consumption in Engine 2: 6,053,276 Nm^3
- **TOTAL: 1 3,823,526 Nm^3**

Based on the PCI published in the monthly gas bills from the supplier NEXUS, the natural gas consumption measured in lower calorific value is as follows:

Month	*Engine No. 1 [Nm^3/month]*	*Engine No. 2 [Nm^3/month]*	*TOTAL [Nm^3/month]*	*TOTAL [kWhPCI/month]*
Jan-17	767,845	284,606	1,052,451	11,204,395
Feb-17	684.672	210,600	895.271	9,435,265
Mar-17	726.013	213.126	939.140	9,898,533
Apr-17	674,816	590,415	1,265,231	13,291,255
May 17	624,841	551,411	1,176,253	12,432,991
June 17	455.229	724,681	1,179,910	12,474,003
Jul-17	616.297	706,760	1,323,057	13,990,010
Aug-17	516,262	575,806	1,092,068	11,409,924
Sep-17	649,490	480,015	1,129,505	11,738,946
Oct-17	688,344	326,978	1,015,322	10,547,168
Nov-17	667,433	681,984	1,349,417	14,149,987
Dec-17	699.007	706,893	1,405,901	14,757,738
TOTAL	**7,770,249**	**6,053,276**	**13,823,526**	**145.330.215**

3 EQUIVALENT ELECTRICAL PERFORMANCE (REE)

According to Annex I of Royal Decree 661/2007, this type of installation must comply with:

$$REE = \frac{E_e}{Q - \frac{V}{Ref\ H}} \geq 55\%$$

The values obtained during this period are:

- E = 61,823,600 kWh
- Q = 145,330,215 kWh
- V = 33,908,862 kWh
- Ref H = 90% (natural gas fuel for steam and/or hot water generation)

Therefore, the REE in this period is:

$$\boldsymbol{R.E.E} = \frac{61.823.600}{145.330.215 - \frac{33.908.862}{0,9}} = \mathbf{57,43}\ \%$$

The calculation of the REE has been carried out solely for the purpose of verifying compliance with the minimum REE for its permanence in the Special Regime for plants prior to RD 661/2007, according to point 3.2.4 of the Technical guide for the measurement and determination of useful heat, electricity and primary energy savings of High Efficiency cogeneration.